

## **Tag-based Heart Rate Measurements of Harbor Porpoises During Normal and Noise-exposed Dives to Study Stress Responses**

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### **LONG-TERM GOALS**

Marine mammals face potentially dramatic changes in the environment, as well as continued disturbances of their ocean habitat from shipping, sonar, fisheries, oil exploration and other ocean activities. To predict and quantify how marine mammals will respond to natural and anthropogenic stressors, it is essential to understand their physiological limits, the potential plasticity of their diving physiology, and their physiological responses to stress. The typical mammalian startle or stress response to an acoustic stressor is increased heart rate, cardiac output and ventilation rate (Graham 1979), all which are contrary to the typical marine mammal dive response (Scholander 1940). Information on the acute stress response during diving is essential to predict how potential stressors effect oxygen and nitrogen management and can provide information on the level of stress the animals routinely experience. Here we examine the dive heart rate, ventilation rate and activity in both captive and wild porpoise to better understand the dive response and how it may be overruled by noise exposure. We are accessing the acute stress response to an acoustic stressor by comparing heart rate, ventilation rate, and activity between control and exposure dives.

### **OBJECTIVES**

This study uses modified Dtag3 data loggers to record diving electrocardiograms, acceleration, orientation, pressure and acoustic data in captive and wild harbor porpoises. The specific objectives are 1) Quantify the physiological (heart and ventilation rates) and behavioral response (activity) to acoustic stimuli in captive porpoises by examining differences between the control and controlled noise exposure trials; and 2) study the dive heart rate, activity and ventilation rate of wild porpoises and opportunistically examine the physiological and behavioral responses to absolute noise levels that

they may be exposed to during routine behaviors. Using harbor porpoises as model species, this study is providing novel information on the capability to use non-invasive, multi-sensor tags to quantify the impact of potential stressors such as sound on physiological systems in cetaceans in the wild.

## APPROACH

### *Objective one: Physiological and behavioral response to acoustic stressors*

Dive heart rate and behavioral response to acoustic stimuli is being examined in two harbor porpoises housed in net pens (size: 35 x 10 x 5 m (L x W x D)) at the Fjord and Bælt center using two protocols: 1) experimental and 2) opportunistic. For the experimental protocol porpoises have been trained to perform prey capture dives in a range of dive durations while instrumented with an ECG Dtag3 data logger. Experimental sessions consisted of a block of 4-6 experimental dives (2-3 controls and 2-3 noise exposure in random order). There were 4 experimental treatments that varied in 1) dive duration (predictable short dives or random medium duration dives) and 2) acoustic stimulus (sonar or startle). Session order was mixed to prevent habituation. In addition to the experimental sessions, we will opportunistically obtain data for both control dives (no acoustic stimuli) and noise exposure dives using passing boats to which the porpoises display strong and stereotyped behavioral startle responses. For all dives we are determining a) diving heart rate, b) maximum heart rate during a dive, c) minimum heart rate, d) heart rate variability, and e) rate of initial heart rate decline. In addition, we are examining the change in heart rate by analyzing pre-exposure, exposure, and post-exposure heart rate. We will compare heart rate profiles, ventilation rate and activity in dives of similar duration between control and noise exposure trials.

Drs. Peter Madsen and Birgitte McDonald will be responsible for data collection and analysis. Mark Johnson will provide assistance with the data logger and analysis. The animals are housed at the Fjord and Bælt center under the care of head trainer Jakob Christiansen.

### *Objective two: Dive heart rate in wild porpoises*

Porpoises accidentally caught in pound nets are being instrumented with an ECG Dtag3 data logger upon release. The tags are deployed with four suction cups programmed to release after 48 hours. Recovery from small boats is aided by built in VHF antennas following establish procedures (Soto et al. 2008). This technique was recently used to successfully collect data from six wild harbor porpoises. Between 2014 and 2016 we will tag 3-5 animals. We will obtain the first diving heart rate data from a wild porpoise and be able to relate this to dive duration, depth, activity and ventilation rates. Additionally, due to the acoustic data collection capabilities of the data loggers we will opportunistically be able to examine the heart rate response to acoustic stimuli while at sea.

Drs. Peter Madsen and Birgitte McDonald will be responsible for data collection and analysis. Mark Johnson will provide assistance with the data logger and analysis. Captures will be conducted in collaboration with a research group led by Jonas Teilmann (Marine Mammal Research, Institute of Bioscience, Aarhus University).

## WORK COMPLETED

*Objective 1:* We have completed the experimental sessions at the Fjord and Bælt center and the data is currently being analyzed. Each animal performed 2 sessions of each treatment (Table 1). Once the data analysis is complete we may conduct additional sessions to supplement the data. We limited session numbers to prevent habituation to acoustic stimuli. The animals are currently being trained to wear the

tag for extended periods of time in between training sessions. Once they are trained to wear the tag for a minimum of 1 hr we will begin the opportunistic studies.

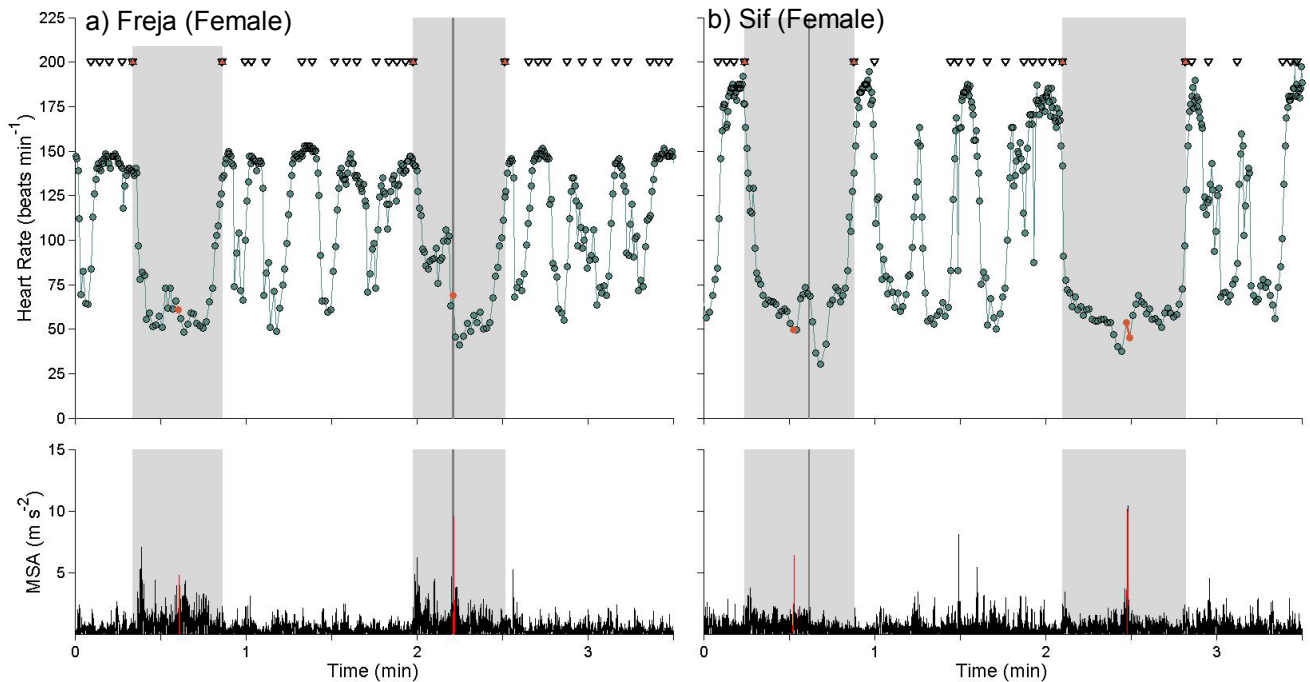
**Table 1: Experimental design and session totals**

| <b>Duration</b>                         | <b>Acoustic stimulus</b>  |  |
|---|---|--|
|   | Sonar<br>(6-9 kHz upswing, 0.5 s)<br>Received levels : 120-155 dB | Startle - white noise<br>(peak 35-45 kHz, 0.05 s)<br>Received levels: 120-170 dB |
| Short<br>(6 dives, 1 fish each)         | 2 sessions each porpoise  | 2 each porpoise  |
| Medium<br>(4 dives, mix of 4 or 8 fish) | 2 each porpoise   | 2 each porpoise  |

*Objective 2:* In November 2015 we deployed a prototype field EKG Dtag 3 on a wild porpoise. Unfortunately due to currents and weather we were unable to recover the tag. Testing of a 2<sup>nd</sup> prototype field EKG Dtag3 was conducted with bottlenose dolphins in Sarasota in May 2015. We successfully deployed and recovered the tag on three dolphins, the longest deployment was 7 hours. Although we did not get a good ECG signal, these deployments gave us the opportunity to test electrode placement and use this knowledge to increase the likelihood of success in wild porpoises. The tag will be deployed on porpoises in Denmark in Fall 2015.

## RESULTS

We investigated dive  $f_H$  and the effects of an acoustic stressor in two captive porpoises using a Dtag3 data logger to record dive behavior,  $f_H$ , and ventilations during active prey capture dives. We obtained data from 72 experimental dives (24 short sonar, 24 short startle, 12 medium sonar, and 12 medium startle). During 50% of these dives they were exposed to acoustic stimuli with a received level between 120 – 170 dB re 1 $\mu$ Pa (rms). In all dives,  $f_H$  decreased compared to surface rates; however, the relationship between dive  $f_H$  and dive behavior was complex. Dive  $f_H$  was variable even in short duration dives, suggesting the conscious ability to regulate  $f_H$  in relation to dive type, duration, and activity. During noise exposure trials porpoises exhibited a decrease or no change in heart rate, although they occasionally displayed a behavioral response (Figure 1). The most pronounced heart rate response for both porpoises was during the first sonar exposure (received level 155 dB re 1 $\mu$ Pa (rms)). Despite a rapid decrease in heart rate (24 beats min<sup>-1</sup> (Freja) and 38 beats min<sup>-1</sup> (Sif)), there was no behavioral response in the video or acceleration signal (MSA) during or immediately following the stimulus (Figure 1). However, one of the porpoises did unusually end her dive early before returning to the trainer. We are currently processing the data to test for more subtle changes in heart rate and to tease apart the relationship between a behavioral and physiological response. Our preliminary data suggests that evolutionary pressures may have resulted in a physiological stress response that conserves or maintain oxygen management when diving, allowing the animals to stay at depth longer.



**Figure 1.** Dive heart rate and activity during control and noise exposure dives from two captive porpoises (a and b). In all dives heart rate decreased (top panel), but during noise exposure trials, heart rate did not change, or decreased more after the acoustic stressor. This figure shows the heart rate response to the first sonar exposure (received level 155 dB for both animals). Dives are highlighted with light grey shading, acoustic stimuli are indicated by the dark grey line, respirations are indicated with triangles on the top, and prey capture is indicated by the orange shading. The top panel shows the respiration and heart rate response. The bottom panel shows the activity of the porpoise using minimum specific acceleration as an activity index (MSA). Although there is an increase in activity associated with prey capture (orange), there is no increase in activity associated with the sonar exposure.

## IMPACT/APPLICATIONS

This study directly addresses two of the ONR Marine Biology Program thrusts: Diving physiology and stress physiology. We are obtaining important diving physiology data for the harbor porpoise using a combination of field and laboratory studies. Due to their small size and ability to be studied in captivity and in the wild, harbor porpoises are a good model species to develop and validate new techniques for studying diving physiology and the stress response in a wild cetacean that can then be used in future studies of larger toothed whales, such as beaked whales. We are investigating the relationship between dive behavior and the heart rate response in harbor porpoises and we will for the first time document the level of bradycardia in a wild cetacean. This information is critical to understanding not only how cetaceans manage oxygen and nitrogen during routine activities, but also how plastic their oxygen store management is, which is key to understanding their ability to adapt to a changing environment. The controlled and opportunistic noise exposure study is providing information on how the stress response influences the ability for cetaceans to manage oxygen and nitrogen during diving. This data is essential for use by the Navy in estimating the impact of naval exercises (i.e. mid-frequency sonar) on marine mammals.

## RELATED PROJECTS

This project is building on an ongoing project investigating diving physiology of harbor porpoises (“Field energetics and diving physiology of a small cetacean, the harbor porpoise”, NSF International Postdoctoral Fellowship awarded to Birgitte McDonald, Award #: 1159123). In the above study we investigated the relationship between dive behavior and activity in 3 captive porpoises . In the ONR funded project we used a similar study protocol to build upon our finding by investigating how an acoustic stressor impacts the ‘natural’ dive response’.

## REFERENCES

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